(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) Publication number: **0 177 963 A2**

(12) EUROPEAN PATENT APPLICATION

(21) Application number: 85112868.6

(22) Date of filing: 10.10.85

(51) Int. Cl.⁴: **H 04 B 1/66**

(30) Priority: 12.10.84 JP 214599/84

(43) Date of publication of application: 16.04.86 Bulletin 86/16

(84) Designated Contracting States: AT DE FR GB NL

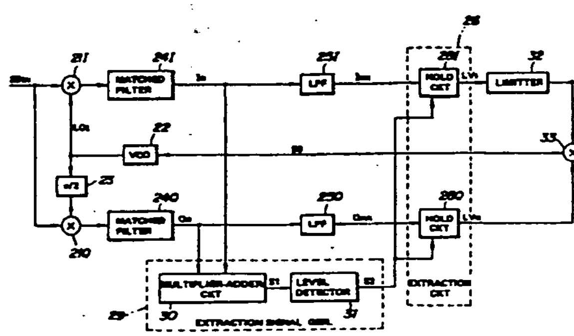
(71) Applicant: SONY CORPORATION, 7-35 Kitashinagawa 6-Chome Shinagawa-ku, Tokyo 141 (JP)

(72) Inventor: Fujita, Masahiro, c/o SONY CORPORATION 7-35 Kitashinagawa 6-chome, Shinagawa-ku Tokyo (JP)

(74) Representative: Patentanwälte TER MEER - MÜLLER - STEINMEISTER, Mauerkircherstrasse 45, D-8000 München 80 (DE)

(54) Decoder for spectrum diffusion signals.

(57) A decoder for spectrum diffusion signals is capable of reproducing data from received a spectrum diffusion signal (SS_{IN}), such as sattellite communication signals without performing PN synchronization. The decoder comprises a correlation detecting means (24_1) comprising a matched filter which produces a backdiffusion signal (I_R) when a received spectrum diffusion signal (SS_{IN}) correlates with a Gold code for a specific channel of a station, an extraction signal generator means (29) for detecting the epoch position of a peak of a triangular wave which appears in the output of the correlation detecting means (24_1) when correlation between the spectrum diffusion signal (SS_{IN}) and the specific Gold code identifying the corresponding channel is established, and a data output extracting means (26) responsive to the extraction signal (S_2) to extract the back-diffusion signal (I_R) and reproduce the resulting data. In this arrangement, the extraction signal generator means (29) is responsive to the peak of the triangular-form wave in the back-diffusion signal (I_R) from the correlation detecting means (24_1) to output the extraction signal (S_2). The extraction signal (S_2) is sent to the data output extraction means (26) to extract back-diffusion signal (I_R) from the output of the correlation detecting means (24_1) and reproduce the data output. Therefore, according to the invention, it is unnecessary to perform PN synchronization in order to obtaining data from the spectrum diffusion signal (SS_{IN}).



EP 0 177 963 A2

DECODER FOR SPECTRUM DIFFUSION SIGNALS

BACKGROUND OF THE INVENTION

The present invention relates generally to a decoder for spectrum diffusion signals, which is specially adapted for satellite communications utilizing spectrum diffusion signals.

Spectrum diffusion communications systems (hereafter called as ''SS communications systems'') are know to be advantageous in that they can use pseudo-random-noise signals (hereafter referred to as ''PRN signal'') which allow sufficiently precise frequency channel selection and thus satisfactorily avoid interference among communication channels. Therefore, information security can be guaranteed by use of such SS communications systems. In addition, such SS communications systems have the advantage than PRN signals have a relative high band width for modulating data signals.

In such SS communications systems, received satellite signals must be demodulated in the receiving station. In order to demodulate the satellite signal, processing by back-diffusion has to be performed utilizing a Gold code specific to the station to keep the specific communications channel secure.

For such back-diffusion process, it has been conventionally believed that the phase of the Gold code must be synchronized with the phase of the received PRN signal by the decoder itself when checking the codes for a match. This synchronization will be referred to hereafter as ''PN synchronization''. Therefore, conventional decoders for spectrum diffusion signals have required means for performing PN synchronization, such as sliding correlating loops or matched filters or the like. Such means for performing PN synchronization prevents simplification of the decoder circuitry.

SUMMARY OF THE INVENTION

Therefore, it is a principle object to provid a decoder which has a simpler structure tha conventional decoders.

Another object of the invention is to provid a decoder which does not require a PN synchronizatio device.

In order to accomplish the aforementioned and other objects, a decoder for spectrum diffusion signals, according to the present invention, can reproduce data from received SS signals without performing PN synchronization.

The decoder comprises a correlation detecting means comprising a matched filter which produces a back-diffusion signal when a received spectrum diffusion signal correlates with a Gold code for a specific channel of a station, an extraction signal generator means for detecting the epoch position of a peak of a triangular wave which appears in the output of the correlation detecting means when correlation between the spectrum diffusion signal and the specific Gold code identifying the corresponding channel is established, and a data output extracting means responsive to the extraction signal to extract the back-diffusion signal and reproduce the resulting data.

In the arrangement set forth above, the extraction signal generator means is responsive to the peak of the triangular-form wave in the back-diffusion signal from the correlation detecting means to output the extraction signal. The extraction signal is sent to the data output extraction means to extract back-diffusion signal from the output of the correlation detecting means and reproduce the data output. Therefore, according to the invention, it is unnecessary to peform PN synchronization in order to obtaining data from the spectrum diffusion signal.

According to one aspect of the invention, a decoder for spectrum diffusion signals comprises a correlation means for comparing a PRN signal included in the spectrum diffusion signal with a Gold code identifying a specific channel, the correlation means producing a back-diffusion signal when the PRN signal matches the Gold code, an extraction signal generator means, responsive to the back-diffusion signal, for producing an extraction signal at a timing near which the back-diffusion signal value reachs a peak, and an extraction means, responsive to the extraction signal, for extracting a data signal from the back-diffusion signal.

The correlation means produces a triangular wave each time the PRN code matches the Gold code.

The decoder further comprises means for forming a frequency component enveloped by the triangular signal. The frequency component enveloped by the triangular signal has a frequency twice as high as a carrier wave in the spectrum diffusion signal. The frequency component forming means comprises a voltage-controlled oscillator and a multiplier, which voltage-controlled oscillator produces a local oscillation signal having a frequency substantially corresponding to that of the carrier wave, and which multiplier receives the spectrum diffusion signal and multiplies the spectrum diffusion signal by the local oscillation signal to form the envelope.

The decoder further comprises an oscillation controlling means associated with the voltage-controlled oscillator for controlling the latter so as to adjust the phase of the local oscillation signal to match the phase of the carrier wave of the spectrum diffusion signal. The oscillation control means comprises a multiplier receiving the spectrum diffusion signal and a local oscillation signal, the phase of which is shifted

by a phase-shifter to a given offset from the phase o the local oscillation signal output by the voltage-controlled oscillator, a second correlation means for producing a back-diffusion signal including a triangular wave produced when the PRN signal matches the Gold code, a filter for removing high frequency components from the back-diffusion signal of the second correlation means and outputting an envelope signal, and a holding circuit receiving the envelope signal and holding the signal level thereof in response to the extraction signal, and a multiplier multiplying the reproduced data signal and the output of the holding circuit so as to derive an oscillation control signal for controlling the signal phase of the local oscillation signal of the voltage-controlled oscillator.

The extraction signal generator comprises a multiplier-adder which derives the squares of each of the back diffusion signals of the correlation means and the second correlation means, and then adds the squares to produce a sum indicative signal, and a level detector responsive to the sum indicative value exceeding a given value to feed the extraction signal to the extraction circuit.

In the alternative, the frequency component forming means comprises a delay circuit and a multiplier, the delay circuit transmitting the back-diffusion signal after a given delay time, and the multiplier multiplying the back-diffusion signal transmitted directly by the correlation means with the delayed back-diffusion signal from the delay circuit to generate the frequency components enveloped by the triangular wave and having a frequency twice as high as the carrier wave of the spectrum diffusion signal. The extraction signal generator means comprises an envelope detector producing an envelope indicative signal, and a level detector for monitoring the level of the envelope

indicative signal and outputting the extraction signal when the signal level of the envelope indicative signal exceeds a given level.

The correlation means outputs more than one triangular wave signals during a period corresponding to one cycle of the Gold code.

According to another aspect of the invention, a decoder for spectrum diffusion signals comprises a correlation means, receiving the spectrum diffusion signal, for comparing a PRN signal contained in the spectrum diffusion signal with a given Gold code which identifies a communication channel, and producing a back-diffusion signal including a data component representative of the data indicative phase-shift of the spectrum diffusion signal, an extraction signal generator associated with the correlation means for detecting peak values of the data component and producing an extraction signal at a timing near the peak value of the data component, and an extraction circuit, receiving the back-diffusion signal and responsive to the extraction signal to extract the data component from the back-diffusion signal.

According to a further aspect of the invention, a process for reproducing data signal from a spectrum deffusion signal comprising the steps of:

receiving the spectrum diffusion signal, comparing a PRN signal contained in the spectrum diffusion signal with a given Gold code which identifies a communication channel, and producing a back-diffusion signal including a data component representative of the data indicative phase-shift of the spectrum diffusion signal;

detecting peak values of the data component and producing an extraction signal at a timing near the peak value of the data component; and

extracting the data component from the

back-diffusion signal in response to the extractioı signal.

The data component is in the form of a triangular wave each time the PRN code matches the Gold code.

The process further comprises a step of forming a frequncy component enveloped by the triangular signal. The frequency component enveloped by the triangular signal has a frequency twice as high as a carrier wave in the spectrum diffusion signal.

The process further comprises a step of controlling phase of a local oscillation signal utilized for forming the frequency component so as to adjust the phase of the local oscillation signal to match the phase of the carrier wave of the spectrum diffusion signal.

In the alternative, the frequency component is formed by transmitting the back-diffusion signal after a given delay time, and multiplying the back-diffusion signal transmitted directly with the delayed back-diffusion signal to generate the frequency components enveloped by the triangular wave and having a frequency twice as high as the carrier wave of the spectrum diffusion signal.

BREIF DESCRIPTION OF THE DRAWINGS

The present invention will be understood from the detailed description given herebelow and from the accompanying drawings of the preferred embodiment of the invention, which, however, should not be taken to limit the invention to the specific embodiment, but are for explanation and understanding only.

In the drawings:

Fig. 1 is a block diagram of the preferred embodiment of a decoder for a spectrum diffusion signal according to the invention;

Fig. 2 is a timing chart for some waveforms produced in the components of the decoder;

Fig. 3 is a timing chart showing triangular-form waves making up the output of a correlation detecting means in the decoder;

Fig. 4 shows the characteristics of an oscillation control signal;

Fig. 5 is a timing chart of operation of some components of the decoder;

Fig. 6 is a block diagram of another embodiment of the decoder according to the invention;

Fig. 7 is a block diagram of a further embodiment of the decoder of the invention; and

Fig. 8 is a timing chart for the components shown in Fig. 7.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring now to the drawings, particularly to Fig. 1, the preferred embodiment of a decoder for a spectrum diffusion signal, according to the invention, is specifically adapted to receive a sinusoidal SS signal, which will be referred to hereafter as ''SS_{in} signal''. The carrier wave of the SS_{in} signal is modulated by phase-shifting. The SS_{in} signal waveform satisfies the following equation:

$$SS_{in} = \pm A \cos(\omega_c t + \phi) \quad ..... (1)$$

where ω_c is an angular frequency of the carrier;

ϕ is the phase difference between the SS_{in} signal and the output LO_1 of a voltage controlled oscillator VCO22 which will be described later; and

A is the wave amplitude.

An I-arm side multiplier 21_I and a Q-arm side multiplier 21_Q are built into the decoder. The SS_{in} signal is input to both of the multipliers 21_I and 21_Q. The I-arm side multiplier 21_I also receives the output

LO_I of the voltage-controlled oscillator 22. On th other hand, the Q-side multiplier 21_Q receives the local oscillation signal LO_Q which is a phase-shifted form of the output LO_I of the voltage-controlled oscillator 22. Phase-shifting of the output LO_I of the voltage-controlled oscillator 22 through a phase offset of $\pi/2$ is performed by a phase shifter 23, which phase shifter 23 will be referred to as ''$\pi/2$-phase shifter''. The LO_I signal of the I-arm side multiplier 21_I satisfies the following equation:

$$LO_1 = \cos \omega_c t \quad ..... (2)$$

The LO_I signal is multiplyed by the SS_{in} signal by the I-arm side multiplier 21_I. As a result, the output of the multiplier 21_I may include a signal component at twice the frequency of the carrier wave and a beat component derived from the phase difference between the LO_I signal and the SS_{in} signal. The waveform of the output of the I-arm side multiplier 21_I can be expressed by the following equation:

$$SS_{in} \times LO_I = \pm A[\cos(2\omega_c t + \phi) + \cos\phi] \quad ... (3)$$

The output of the I-arm side multiplier 21_I will be hereafter referred to as I-arm signal I.

On the other hand, the local oscillation signal LO_Q is shifted in phase through $\pi/2$ radians with respect to the phase of the LO_I signal. The local oscillation signal LO_Q satisfies the following equation:

$$LO_Q = \sin \omega_c t \quad ..... (4)$$

The local oscillation signal LO_Q is multiplied by the SS_{in} signal by the Q-arm side multiplier 21_Q. The multiplier 21_Q outputs a result with a signal component at twice the frequency of the carrier wave and a beat

component. The resultant output of the multiplier 21_Q will be hereafter referred to as ''Q-arm signal Q''.

The Q-arm signal Q satisfies the following equation:

$$SS_{in} \times LO_Q = \pm A\ [\sin(2\omega_c t + \phi) + \sin \phi] \ \ldots . \ (5)$$

As will be appreciated herefrom, the beat component in the I-arm signal is a cosine wave (cos ϕ) and the beat component of the Q-arm signal is a sine wave (sin ϕ). Therefore, the beat components of the I-arm signal and Q-arm signal are offset in phase by 90° with respect to each other.

The I-arm signal and the Q-arm signal are sent to matched filters 24_I and 24_Q respectively. The matched filters 24_I and 24_Q comprises a <u>surface acoustical wave (SWA)</u> filter which simulates a comb-teeth pattern corresponding a logical code arrangement of bits defining the Gold code for the specific channel. The matched filters 24_I and 24_Q form a correlation detecting means and each receives data from each sample period of the signal corresponding to one cycle of the Gold code when the data coincides with a ''transmit'' bit the Gold code. The matched filters 24_I and 24_Q compare the received signals with the bits of the preset Gold code in these fixed time blocks. The matched filters 24_I and 24_Q output back-diffusion signals I_R and Q_R. As will be seen from Fig. 2, the back-diffusion signals I_R and Q_R include triangular-wave components when the PRN signal matches the Gold code of a specific channel. Therefore, every given period T_1 which corresponds one cycle of the Gold code, the triangular wave appears in the back-diffusion signal. The back-diffusion signals I_R and Q_R have frequency components at twice the frequency of the carrier wave and a beat component, as indicated by the foregoing

equations (3) and (5) and as shown in Fig. 2(A).

The back-diffusion signals I_R and Q_R are sent to low-pass filters 25_I and 25_Q which remove the higher frequency components. The wave-form of the output of the low-pass filters 25_I and 25_Q is shown in Fig. 2(B). The output of the low-pass filters 25_I and 25_Q serve as triangular-wave envelope signals I_{RX} and Q_{RX}. The triangular wave envelope signals I_{RX} and Q_{RX} are sent to respectively corresponding holding circuits 28_I and 28_Q of an extraction circuit 26.

On the other hand, the back-diffusion signals I_R and Q_R are sent to a quadratic multiplier 30 in an extraction signal generator circuit 29. The output of the quadratic multiplier 29 can be represented by the following equation:

$$S_1 = I_R{}^2 + Q_R{}^2 \quad .... \ (6)$$

Summing the squares of the back-diffusion signals I_R and Q_R, the frequency components of which vary between positive and negative phases, has the same effect as adding the absolute amplitudes of the back-diffusion signals I_R and Q_R. The resultant value behaves in the same manner as the triangular-wave envelope signals I_{RX} and Q_{RX} from the low-pass filters 25_I and 25_Q.

The output S_1 of the multiplier-adder 30 is sent to a level detector circuit 31. The level detector circuit 31 has a threshold value which corresponds to a predetermined level L_1 proportional to the amplitude of the triangular-wave envelope signal I_{RX} and Q_{RX}, and is compared with the output S_1 of the multiplier-adder circuit 30. The level detector circuit 31 outputs a detector signal S_2 which is shown in Fig. 2(C) when the output level S_1 exceeds the threshold value. The level detector circuit 31 feeds the detector signal S_2 to the holding circuits 28_I and 28_Q of the extraction circuit

26. This detector signal S_2 serves as an extraction trigger signal.

The holding circuits 28_I and 28_Q are sample the triangular-wave envelope signals I_{RX} and Q_{RX} respectively in response to the extraction signal S_2 from the level detector circuit 31. It should be appreciated that the polarity of the triangular-wave envelope signals I_{RX} and Q_{RX} corresponds to the phase-shift direction of the corresponding back-diffusion signals I_R and Q_R. Therefore, the values held in the holding circuits 28_I and 28_Q are at or near the peak values of the triangular waves in the back-diffusion signals I_R and Q_R.

The triangular waves in the back-diffusion signals I_R and Q_R appearing in each cycle T_1 of the Gold code have a higher frequency than occurrences of the data signal which is transmitted in the form of a phase-shifted modulated signal. Therefore, the holding circuits 28_I and 28_Q will hold positive signal levels corresponding to a logical ''1'' while the data signal has a phase-shift representative of logical ''1'' and hold negative signal levels while the phase shift of the data signal represents logical ''0''.

The holding circuits 28_I and 28_Q output level outputs LV_I and LV_Q which respectively to the held signal level. The level output LV_I of the holding circuit 28_I is sent to a limiter 32. The limiter 32 converts the level signal LV_I into binary code having logical values, i.e. ''0'' or ''1'' while limiting the input signal level to within predetermined negative and positive reference levels. This binary code is output as reproduced data signal INF.

The reproduced data signal INF is also sent to a multiplier 33, which also receives the level signal LV_Q from the holding circuit 28_Q. The data signal INF is multiplied by the level signal LV_Q of the holding

circuit 28_Q. The resultant output S_3 of the multiplier 33 is applied to the voltage controlled oscillator 22 as an oscillation control signal.

As set forth above, the level signals LV_I and LV_Q of the holding circuits 28_I and 28_Q are derived from the envelope signals I_{RX} and Q_{RX} which are formed by removing the carrier components from the back-diffusion signals I_R and Q_R. Therefore, the amplitude of the level signals LV_I and LV_Q varies with the frequency of the beat components which correspond to the phase difference ϕ between the carrier wave of the SS_{in} signal and the local oscillation signal LO_I of the voltage-controlled oscillator 22. Taking this into account, the output level LV_I of the triangular waves in the back-diffusion signals I_R and Q_R oscillate sinusoidally between positive and negative peaks depending upon the beat frequencies as shown in Figs. 3(A) and 3(B). As mentioned previously, the variation of the output level LV_I in the I-arm side corresponds to its beat component, i.e. cos ϕ. Likewise, the variation of the output level LV_Q in the Q-arm side follows its beat component, i.e. sin ϕ.

The level signal LV_1 of the holding circuit 28_I in the I-arm side is converted into the reproduced data signal INF in the limiter 32. Therefore, the reproduced data signal INF varies between +1 and -1 which corresponds to a phase shift between $+\pi/2$ and $-\pi/2$. Therefore, the oscillation control signal S_3 can be represented by the following equation:

$$\begin{aligned} S_3 &= (\pm A \sin \phi) \times (\pm 1) \\ &= A \sin \phi \qquad \ldots\ldots (7) \end{aligned}$$

In the foregoing equation (7), ϕ represents the phase difference between the carrier wave in the SS_{in} signal and the oscillation signal LO_I from the

voltage-controlled oscillator 22. Therefore, the oscillation control signal S_3 varies according to the equation (7) as the phase difference ϕ varies between $+\pi/2$ and $-\pi/2$. By controlling the voltage controlled oscillator 22 utilizing the oscillation control signal S_3 derived as set forth above, the influence of the beat components in the triangular wave P_R of the level signal LV_I can be eliminated.

Specifically, by suitably controlling the voltage controlled oscillator 22, the phase difference between the carrier wave in the SS_{in} signal and the oscillation signal LO_I can be controlled to zero. This fully cancels the influence of the beat component on the peak value of the triangular wave P_R in the level signal LV_I. Therefore, the level of the level signal LV_I accurately reflects the data value intended by the magnitude of phase shift.

According to the shown embodiment, the SS_{in} signal is first converted into the I-arm signal I and the Q-arm signal Q, each including a frequency component at twice the frequency of the carrier wave by multiplication by the local oscillation signal LO_I and LO_Q by the multipliers 21_I and 21_Q. The matched filters 24_I and 24_Q output the back-diffusion signals I_R and Q_R, which include triangular waves P_R generated each time the PRN code in the SS_{in} signal matches the Gold code identifying the specific channel. Each of the back-diffusion signals I_R and Q_R is superimposed on the frequency of the voltage controlled oscillator output and the beat component originating from the phase difference of the carrier wave of the SS_{in} signal and the local oscillation signal from the voltage controlled oscillator 22 is thereby eliminated.

As set forth above, since the local oscillation signals LO_I and LO_Q supplied to the multipliers 21_I and 21_Q are mutually phase-shifted by

90^{o}, the back-diffusion signals I_R and Q_R from the matched filter 24_I and 24_Q are also offset in phase by 90^{o}, as shown in Figs. 5(A_1) and 5(A_2). This phase shift between the back-diffusion signals I_R and Q_R occurs due to phase difference between their beat components. Therefore, the triangular waves P_R of the back-diffusion signals I_R and Q_R appear at different times, which timing difference corresponds to a phase difference of 90^{o} between the beat components.

When a triangular wave P_R appears in either one of the back-diffusion signals I_R and Q_R, the data signal phase shift keying modulated onto carrier wave in the SS_{in} signal is obtained through the corresponding matched filter 24_I and 24_Q.

The extraction signal generator circuit 29 employs a multiplier-adder circuit to obtain the sum of the squares of the back-diffusion signals I_R and Q_R. Based on this sum, the level detector circuit 31 detects the epoch of the peak of the triangular-wave P_R in the back-diffusion signals and produces the extraction signal S_2, as shown in Fig. 5(B). In this arrangement, since the epoch of the peak of the triangular wave is detected based on the squares of the back-diffusion signals I_R and Q_R, the beat component of the back-diffusion signals have no effect on detection of the peak of the triangular wave significant enough to influence the results. Therefore, the extraction signal timing is reliably accurate.

The level signals LV_I and LV_Q vary as shown in Fig. 5(C), in which only the level signal LV_I is shown. The level signals LV_I and LV_Q behave this way because of the phase information imposed on the carrier, which phase shift is indicative of the data to be transmitted, and because of the beat component resulting from the phase shift between the carrier of the SS_{in} signal and the local oscillation signal from the voltage controller

oscillator 22. The limiter 32 converts the level signal LV_I from the holding circuit 28_I into a binary signal varying between +1 and -1. For this purpose, the limiter 32 compares the signal level to a predetermined level such that a reproduced data signal value INF of ''1'' is output when the level signal LV_I exceeds the predetermined level and -1 is output otherwise. This binary reproduced data signal is output as decoder output.

At the same time, the reproduced data signal INF is sent to the multiplier 33. The multiplier 33 is responsive to the reproduced data signal INF to output the oscillation control signal S_3 according to the foregoing equation (7). The oscillation control signal S_3 controls the voltage controlled oscillator 22 so as to reduce the phase shift between the local oscillation signal LO_I and the carrier wave of the SS_{in} signal to zero. When the phase-shift ϕ between the local oscillation signal LO_I and the carier wave of the SS_{in} signal equals zero, the beat component in the back-diffusion signal is completely absent. As a result, the envelopes of the back-diffusion signals I_R and Q_R can be controlled to a given constant value.

As will be appreciated herefrom, the shown embodiment of the decoder for spectrum diffusion signals utilized in the satellite communications, for example, according to the invention, can reproduce data without using a loop for PN synchronization. This help's simplify the decoder per se and also the receiver unit overall, such as GPS (global positioning system) receiver.

Although the above embodiment of the decoder is designed for synchronous detection, the decoder according to the present invention can be applied to other kinds of detection systems. For example, the decoder according to the invention can be applied to

delayed detection system.

Fig. 6 shows another embodiment of a decoder for spectrum diffusion signals according to the present invention, which decoder is suitable for delayed detection. In this embodiment, the SS_{in} signal is input to a matched filter 41. The matched filter 41 outputs a filter output MFO which includes triangular wave P_R when the PRN signal in the SS_{in} signal matches the Gold code identifying the specific channel. As in the preceding embodiment, the triangular waves appear in the filter output MFO at given periods corresponding to the duration of the Gold code.

The filter output MFO is sent to a multiplier 42. The filter output MFO is also sent to a delay circuit 43. The delay circuit 43 delays the filter output MFO by $\pi/2$ and then supplies it to the multiplier 42 as delayed filter output MFOX. In the multiplier 42, the delayed filter output MFOX is multiplied by the filter output MFO input directly. The multiplier 42 thus outputs a multiplier output S_{11}, in which the triangular wave P_R has a frequency twice as high as the carrier wave of the SS_{in} signal. This multiplier output S_{11} has substantially the same waveform as illustrated in Fig. 2(A). The multiplier output S_{11} is sent to a low-pass filter 44. The low-pass filter 44 filters out the carrier component and outputs an envelope output S_{12} which corresponds to the signal shown in Fig. 2(B). This envelope signal S_{12} is input to an extraction circuit 45.

On the other hand, the filter output MFO is also sent to an extraction signal generator circuit 46. The extraction signal generator circuit 46 comprises an envelope detector circuit 47 and a level detector 48. The envelope detector circuit 47 derives an envelope output S_{13} which is representative of the envelope of the filter output MFO. The level detector 48 detects

variations in the envelope signal S_{13} level and output an extraction pulse signal S_{14} at the peak of the triangular wave P_R. The extraction pulse signal S_{14} is sent to the extraction circuit 45. The extraction circuit 45 is responsive to the extraction pulse signal S_{14} to extract the signal level of the envelope signal S_{12} from the low-pass filter and output it as the reproduced data signal INF.

In the arrangement of Fig. 6, the extraction pulse signal S_{14} is generated at a timing coincident with the peak of the triangular wave P_R. Therefore, extraction signals occur at given periods matching the duration of the Gold code. At this timing, the extraction circuit 45 is activated to extract data signal from the envelope signal S_{12} from the low-pass filter 44.

Therefore, according to this embodiment, the data signal can be reproduced without performing PN synchronization, as in the preceding first embodiment.

Although the embodiment shown in Fig. 6 employs a matched filter which generates a triangular wave P_R each time the PRN signal in the SS_{in} signal matches the Gold code, it may be possible to produce more than one triangular wave during each cycle of the Gold code. Increasing the frequency of occurence of the triangular waves P_R in each cycle of the Gold code increase the data volume obtainable from the SS_{in} signal.

An example of a modification to the foregoing embodiments will be described with reference to Fig. 7.

In Fig. 7, a matched filter circuit 51 comprises a pair of parallelly connected matched filters 51_A and 51_B. Both of the matched filters 51_A and 51_B receive the SS_{in} signal and output respective filter outputs MFOA and MFOB. The filter outputs MFOA and MFOB of the matched filters 51_A and 51_B are both sent to a

composition circuit 52. The composition circuit 52 combines the two filter outputs MFOA and MFOB to obtain a composite filter output MF_{out}.

The matched filter 51_B uses a filter pattern which corresponds to a Gold code which matches the PRN signal at a different timing than the matching timing between the Gold code of the matched filter 51_A and the PRN signal in the SS_{in} signal. Specifically, in the shown embodiment, the matched filter 51_B generates a triangular wave P_R at a timing offset from the timing of triangular wave P_R in the filter output MFOA by one half-cycle of the given Gold code, as shown in Fig. 8. Therefore, the triangular waves P_R in the composite filter output MF_{out} occur at every half-cycle of the Gold code.

Therefore, by employing the arrangement of Fig. 7, the decoder can use twice as many sampling points to increase the data transfer rate.

Although the example of Fig. 7 doubles the frequency of the triangular signal in comparison with the embodiments of Figs. 1 and 6, the frequency of occurence of the triangular waves is not to be limited to the shown embodiments. Any frequency of occurence of the triangular waves can be achieved in various ways.

As will be appreciated herefrom, according to the present invention, the decoder for the spectrum diffusion signal can obtain data from a SS signal, such as satellite signal, without the need for a PN synchronization loop. Therefore, the construction and function of the decoder can be simplified. Thus, the invention fulfills all of the objects and advantages sought therefor.

While specific embodiments have been disclosed in order to facilitate full understanding of the invention, the shown embodiments should be appreciated as mere examples of the present invention. Various

embodiments and modifications to the shown embodiments, which do not depart from the principles of the invention as set out in the appended claims, should be understood to be within the scope of the invention.

CLAIMS:

1. A decoder for spectrum diffusion signals, characterized by:

a correlation means (24_I;41) for comparing a PRN signal included in the spectrum diffusion signal (SS_{IN}) with a Gold code identifying a specific channel, said correlation means (24_I;41) producing a back-diffusion signal (I_R;MFO) when said PRN signal matches said Gold code;

an extraction signal generator means (29;46) responsive to said back-diffusion signal (I_R;MFO), for producing an extraction signal (S_2;S_{14}) at a timing near which said back-diffusion signal value reaches a peak; and

an extraction means (26;45) responsive to said extraction signal (S_2;S_{14}) for extracting a data signal from said back-diffusion signal (I_R;MFO).

2. The decoder as set forth in claim 1, characterized in that said correlation means (24_I;41) produces a triangular wave each time said PRN code matches said Gold code.

3. The decoder as set forth in claim 2, characterized further by means for forming a frequency component enveloped by said triangular signal.

4. The decoder as set forth in claim 3, characterized in that said frequency component enveloped by said triangular signal has a frequency twice as high as a carrier wave in said spectrum diffusion signal.

5. The decoder as set forth in claim 4, characterized in that said frequency component forming means comprises a voltage-controlled oscillator (22) and a multiplier (21_I), which voltage-controlled oscillator (22) produces a local oscillation signal (LO_I) having a frequency substantially corresponding to that of said carrier wave, and which multiplier (21_I) receives said

spectrum diffusion signal (SS_{IN}) and multiplies said spectrum diffusion signal (SS_{IN}) by said local oscillation signal (LO_I) to form said envelope.

6. The decoder as set forth in claim 5, characterized further by an oscillation controlling means associated with said voltage-controlled oscillator (22) for controlling the latter so as to adjust the phase of said local oscillation signal (LO_I) to match the phase of said carrier wave of said spectrum diffusion signal (SS_{IN}).

7. The decoder as set forth in claim 6, characterized in that said oscillation control means comprises a multiplier (21_Q) receiving said spectrum diffusion signal ((SS_{IN}) and a local oscillation signal (LO_Q), the phase of which is shifted by a phase-shifter (23) to a given offset from the phase of said local oscillation signal output (LO_I) by said voltage-controlled oscillator (22), a second correlation means (24_Q) for producing a back-diffusion signal (Q_R) including a triangular wave produced when said PRN signal matches said Gold code, a filter (25_Q) for removing high frequency components from said back-diffusion signal (Q_R) of said second correlation means (245_Q) and outputting an envelope signal (Q_{RX}), and a holding circuit (28_Q) receiving said envelope signal (Q_{RX}) and holding the signal level thereof in response to said extraction signal (S_2), and a multiplier (33) multiplying said reproduced data signal and the output of said holding circuit (28_Q) so as to derive an oscillation control signal (S_3) for controlling the signal phase of said local oscillation signal (LO_I) of said voltage-controlled oscillator (22).

8. The decoder as set forth in claim 7, characterized in that said extraction signal generator (29) comprises a multiplier-adder (30) which derives the squares of each of said back diffusion signals (I_R, Q_R) of said

correlation means (24_I) and said second correlation means (24_Q), and then adds said squares to produce a sum indicative signal (S_1), and a level detector (31) responsive to said sum indicative value exceeding a given value to feed said extraction signal (S_2) to said extraction circuit (26).

9. The decoder as set forth in claim 3, characterized in that said frequency component forming means comprises a delay circuit (43) and a multiplier (42), said delay circuit (43) transmitting said back-diffusion signal (MFO) after a given delay time, and said multiplier (42) multiplying said back-diffusion signal (MFO) transmitted directly by said correlation means (41) with said delayed back-diffusion signal (MFOX) from said delay circuit (43) to generate said frequency components enveloped by said triangular wave and having a frequency twice as high as the carrier wave of said spectrum diffusion signal (SS_{IN}).

10. The decoder as set forth in claim 9, characterized in that said extraction signal generator means (46) comprises an envelope detector (47) producing an envelope indicative signal (S_{13}), and a level detector (48) for monitoring the level of said envelope indicative signal (S_{13}) and outputting said extraction signal (S_{14}) when the signal level of said envelope indicative signal (S_{13}) exceeds a given level.

11. The decoder as set forth in claim 2, characterized in that said correlation means (24_I;41) outputs more than one triangular wave signals during a period corresponding to one cycle of said Gold code.

12. A decoder for spectrum diffusion signals, characterized by;

a correlation means (24_I;41), receiving said

spectrum diffusion signal (SS_{IN}), for comparing a PRN signal contained in said spectrum diffusion signal (SS_{IN}) with a given Gold code which identifies a communication channel, and producing a back-diffusion signal (I_R;MFO) including a data component representative of the data indicative phase-shift of said spectrum diffusion signal (SS_{IN});

an extraction signal generator (29;46) associated with said correlation means (I_R;MFO) for detecting peak values of said data component and producing an extraction signal (S_2;S_{14}) at a timing near said peak value of said data component; and

an extraction circuit (26;45), receiving saidback-diffusion signal (I_R;MFO) and responsive to said extraction signal (S_2;S_{14}) to extract said data component from said back-diffusion signal (SS_{IN}).

13. The decoder as set forth in claim 12, characterized in that said correlation means (24_I;41) produces said data component in the form of a triangular wave each time said PRN code matches said Gold code.

14. The decoder as set forth in claim 13, characterized further by means for forming a frequency component enveloped by said triangular signal.

15. The decoder as set forth in claim 14, characterized in that said frequency component enveloped by said triangular signal has a frequency twice as high as a carrier wave in said spectrum diffusion signal.

16. The decoder as set forth in claim 15, characterized in that said frequency component forming means comprises a voltage-controlled oscillator (22) and a multiplier (21_I), which voltage-controlled oscillator (22) produces a local oscillation signal (LO_I) having a frequency substantially corresponding to that of said

carrier wave, and which multiplier (21_I) receives said spectrum diffusion signal (SS_{IN}) and multiplies said spectrum diffusion signal (SS_{IN}) by said local oscillation signal (LO_I) to form said envelope.

17. The decoder as set forth in claim 16, characterized further by an oscillation controlling means associated with said voltage-controlled oscillator (22) for controlling the latter so as to adjust the phase of said local oscillation signal (LO_I) to match the phase of said carrier wave of said spectrum diffusion signal (SS_{IN}).

18. The decoder as set forth in claim 16, characterized in that said oscillation control means comprises a multiplier (21_Q) receiving said spectrum diffusion signal (SS_{IN}) and a local oscillation signal (LO_Q), the phase of which is shifted by a phase-shifter (23) to a given offset from the phase of said local oscillation signal output (LO_I) by said voltage-controlled oscillator (22), a second correlation means (24_Q) for producing a back-diffusion signal (Q_R) including a triangular wave produced when said PRN signal matches said Gold code, a filter (25_Q) for removing high frequency components from said back-diffusion signal (Q_R) of said second correlation means (24_Q) and outputting an envelope signal (Q_{RX}), and a holding circuit (28_Q) receiving said envelope signal (Q_{RX}) and holding the signal level thereof in response to said extraction signal (S_2), and a multiplier (33) multiplying said reproduced data signal and the output of said holding circuit (28_Q) so as to derive an oscillation control signal (S_3) for controlling the signal phase of said local oscillation signal (LO_I) of said voltage-controlled oscillator (22).

19. The decoder as set forth in claim 18, characterized in that said extraction signal generator (29) comprises a multiplier-adder (30) which derives the squares of each of said back diffusion signals (I_R, I_Q)

of said correlation means (24_I) and said second correlation means (24_Q), and then adds said squares to produce a sum indicative signal (S_1), and a level detector (31) responsive to sum indicative value exceeding a given value to feed said extraction signal (S_2) to said extraction circuit (26).

20. The decoder as set forth in claim 14, characterized in that said frequency component forming means comprises a delay circuit (43) and a multiplier (42), said delay circuit (43) transmitting said back-diffusion signal (MFO) after a given delay time, and said multiplier (42) multiplying said back-diffusion signal (MFO) transmitted directly by said correlation means (41) with said delayed back-diffusion signal (MFOX) from said delay circuit (43) to generate said frequency components enveloped by said triangular wave and having a frequency twice as high as the carrier wave of said spectrum diffusion signal (SS_{IN}).

21. The decoder as set forth in claim 20, characterized in that said extraction signal generator means (46) comprises an envelope detector (47) producing an envelope indicative signal (S_{13}), and a level detector (48) for monitoring the level of said envelope indicative signal (S_{13}) and outputting said extraction signal (S_{14}) when the signal level of said envelope indicative signal (S_{13}) exceeds a given level.

22. The decoder as set forth in claim 13, characterized in that said correlation means (24_I, 41) outputs more than one triangular wave signals during a period corresponding to one cycle of said Gold code.

23. A process for producing data signal from a spectrum diffusion signal characterized by the steps of:

receiving said spectrum diffusion signal (SS_{IN}) comparing a PRN signal contained in said spectrum

diffusion signal (SS_{IN}) with a given Gold code which identifies a communication channel, and producing a back-diffusion signal (I_R;MFO) including a data component representative of the data indicative phase-shift of said spectrum diffusion signal (SS_{IN});

detecting peak values of said data component and producing an extraction signal (S_2;S_{14}) at a timing near said peak value of said data component; and

extracting said data component from said back-diffusion signal (I_R;MFO) in response to said extraction signal (S_2;S_{14}).

24. The process as set forth in claim 23, characterized in that said data component is in the form of a triangular wave each time said PRN code matches said Gold code.

25. The process as set forth in claim 24, characterized further by a step of forming a frequency component enveloped by said triangular signal.

26. The process as set forth in claim 25, characterized in that said frequency component enveloped by said triangular signal has a frequency twice as high as a carrier wave in said spectrum diffusion signal (SS_{IN}).

27. The process as set forth in claim 26, characterized further by a step of controlling phase of a local oscillation signal (LO_I) utilized for forming said frequency component so as to adjust the phase of said local oscillation signal (LO_I) to match the phase of said carrier wave of said spectrum diffusion signal (SS_{IN}).

28. The decoder as set forth in claim 25, characterized in that said frequency component is formed by transmitting said back-diffusion signal after a given delay time, and multiplying said back-diffusion

signal (MOF) transmitted directly with said delayed back-diffusion signal (MOFX) to generate said frequency components enveloped by said triangular wave and having a frequency twice as high as the carrier wave of said spectrum diffusion signal (SS_{IN}).

FIG. 1

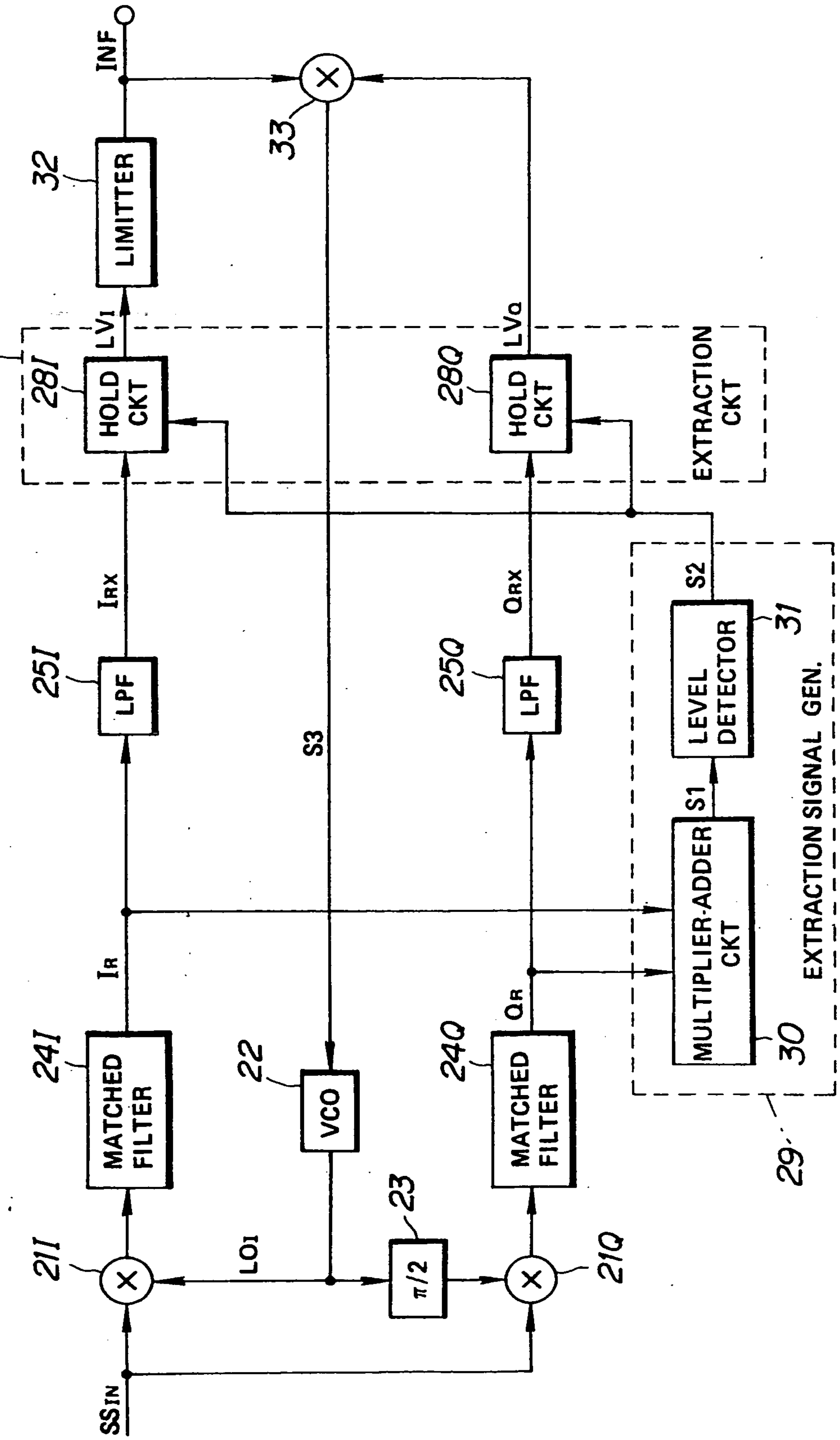

SSIN
21I
LOI
23
π/2
21Q
MATCHED FILTER
24I
22
VCO
24Q
MATCHED FILTER
IR
QR
MULTIPLIER-ADDER CKT
30
EXTRACTION SIGNAL GEN.
29
S1
LEVEL DETECTOR
31
S2
25I
LPF
25Q
LPF
IRX
QRX
S3
28I
HOLD CKT
28Q
HOLD CKT
EXTRACTION CKT
26
LVI
LVQ
32
LIMITTER
33
INF

FIG.2

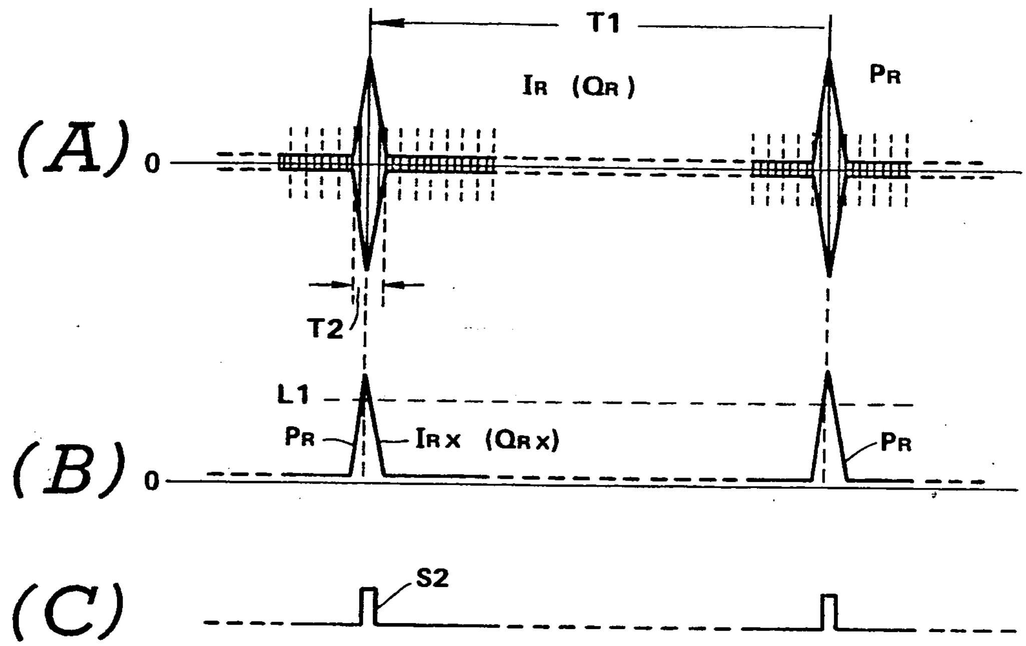


FIG.3

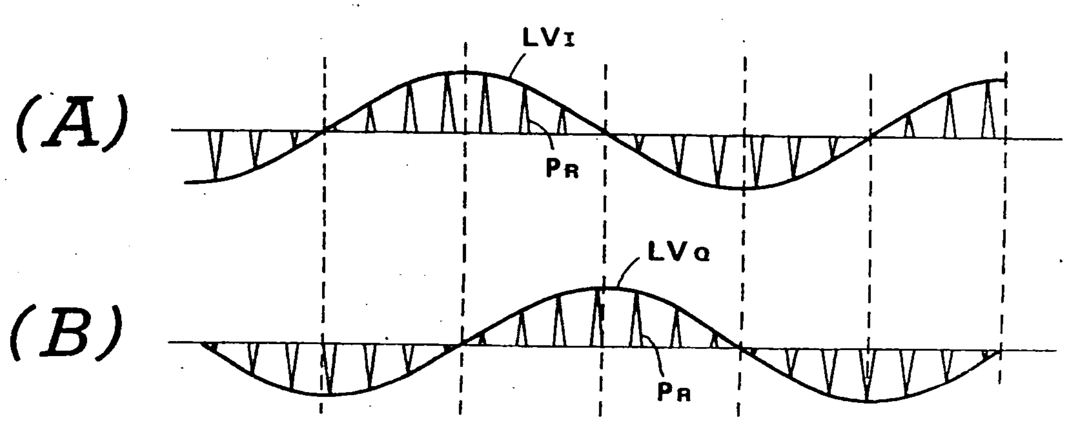


FIG.4

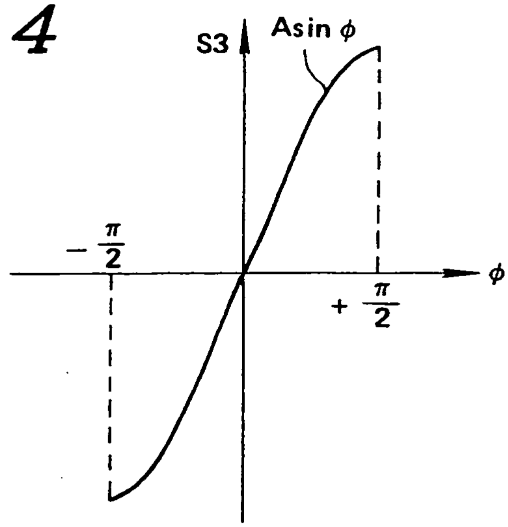


FIG.5

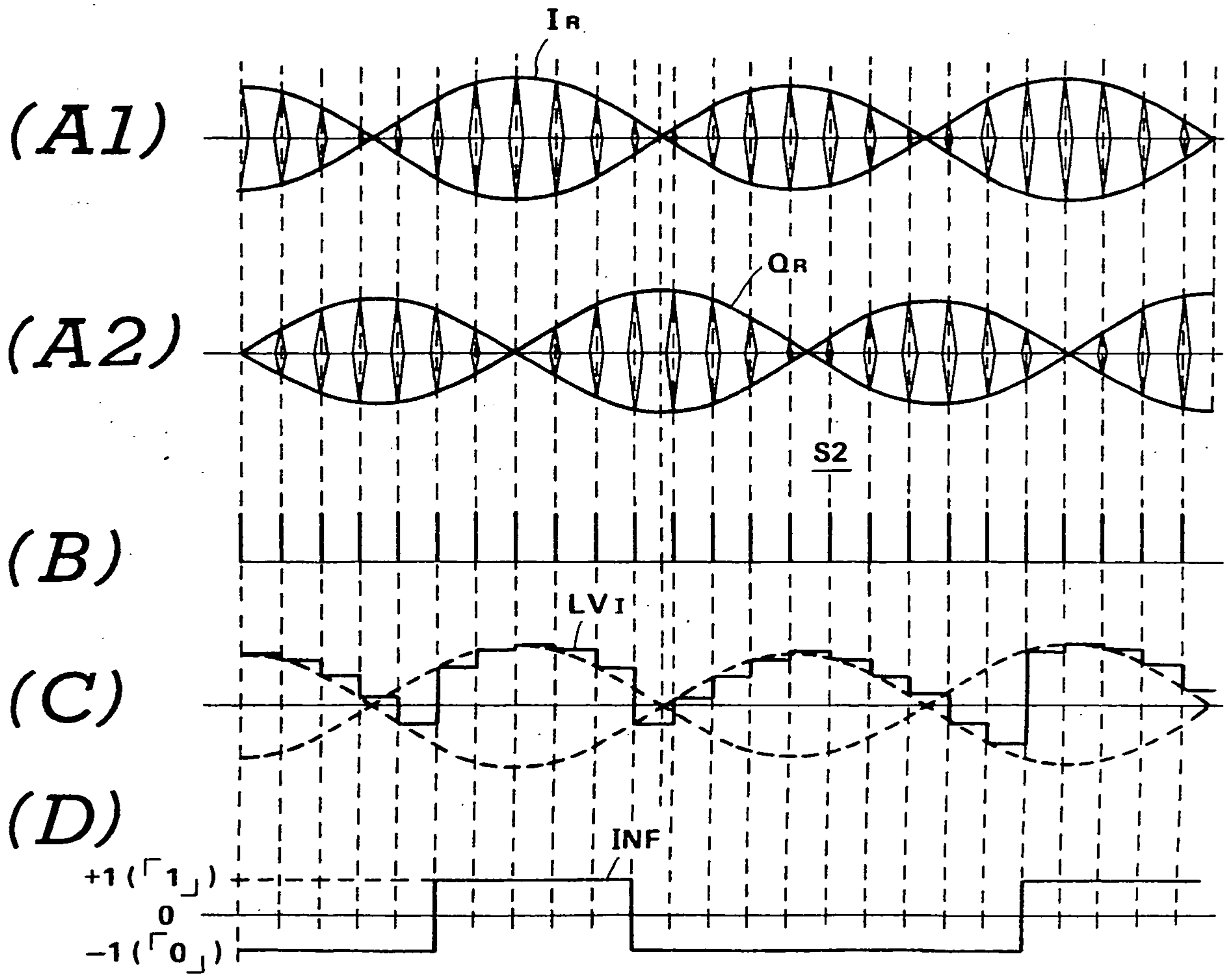


FIG. 6

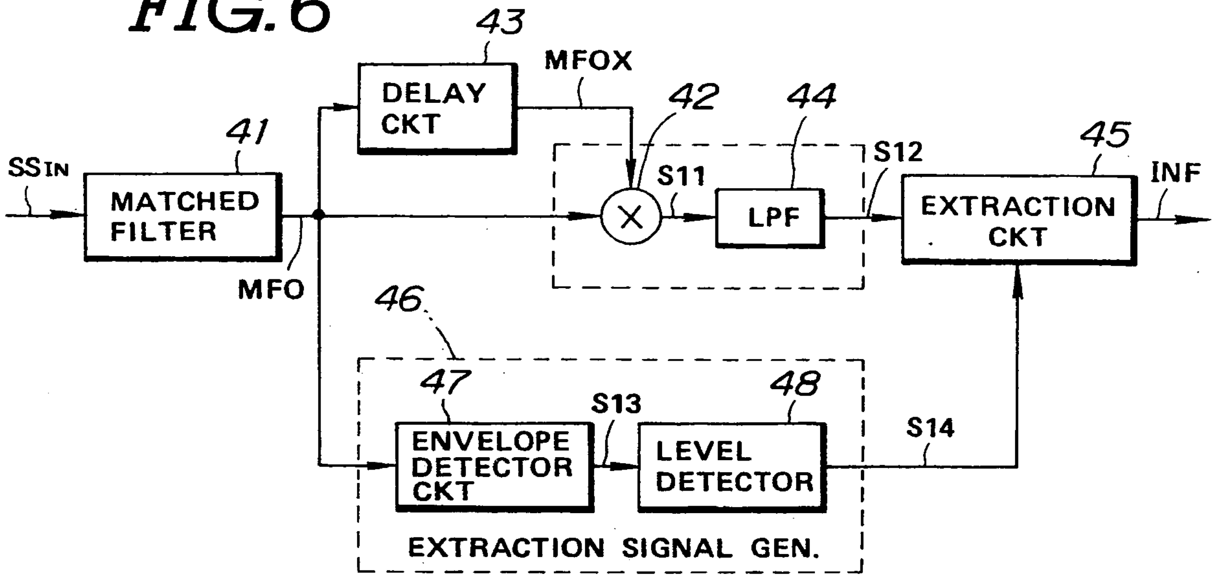


FIG. 7

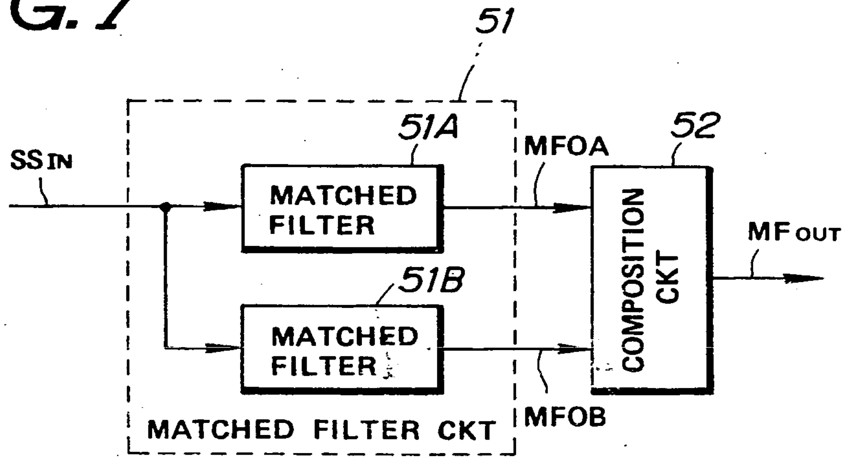


FIG. 8

(A)
(B)
(C)